



DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
SEATTLE REGIONAL OFFICE
1107 NE 45TH STREET, SUITE 350
SEATTLE WA 98105-4631

IN REPLY REFER TO:
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247
2 August 1995

MEMORANDUM

From: Office of Naval Research Resident Representative, Seattle
To: Office of the Chief of Naval Research, Attn: ONR 341MCE/Dr. Michael T. Marron, 800 N. Quincy St., BCT 1, Room 823, Arlington, VA 22217-5660

Subj.: REQUEST FOR FINAL TECHNICAL APPROVAL, GRANT N00014-92-J-1581,
R&T PROJECT CODE: s400074fel03, STANFORD UNIVERSITY, PRINCIPAL
INVESTIGATOR IS PROFESSOR RICHARD H. PATELL

1. This office is in the process of closing subject contract. We have been advised that the final technical report has been submitted.
2. So that closeout may continue, please provide this office with information as to whether technical requirements have been performed satisfactorily.
3. Should you have any questions, do not hesitate to call us at (206) 526-3183. Confirmation by e-mail will be accepted by this office.

Eleanor A. Dixon
ELEANOR A. DIXON
Procurement Technician

Copy to: DTIC (w/attach)

*****DO NOT DETACH*****
FIRST ENDORSEMENT on ONR ltr, dtd August 2, 1995

From: Scientific Program Officer, ONR 341MCE

To: Office of Naval Research, Seattle

1. Returned for necessary action.

2. I certify that all technical requirements under subject contract are:

Satisfactory

Unsatisfactory

Comments:

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Date

Scientific Program Officer



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11 Jul 97

From: Director, Office of Naval Research, Seattle Regional Office, 1107 NE 45th St., Suite 350,
Seattle, WA 98105

To: Defense Technical Center, Attn: P. Mawby, 8725 John J. Kingman Rd., Suite 0944,
Ft. Belvoir, VA 22060-6218

Subj: RETURNED GRANTEE/CONTRACTOR TECHNICAL REPORTS

1. This confirms our conversations of 27 Feb 97 and 11 Jul 97. Enclosed are a number of technical reports which were returned to our agency for lack of clear distribution availability statement. This confirms that all reports are unclassified and are "APPROVED FOR PUBLIC RELEASE" with no restrictions.
2. Please contact me if you require additional information. My e-mail is *silverr@onr.navy.mil* and my phone is (206) 625-3196.

Robert J. Silverman
ROBERT J. SILVERMAN

RECORDED AND INDEXED
11 JUL 1997



STANFORD UNIVERSITY
ELECTRICAL ENGINEERING DEPARTMENT

PROFESSOR RICHARD PANTELL
310 McCULLOUGH BUILDING

STANFORD, CA 94305
(415) 723-2564
FAX (415) 723-4659

Scientific Officer Code: 1141MB
Michael Marron
Office of Naval Research
800 North Quincy Street
Arlington, VA 22217-5000

July 18, 1995

Dear Mr. Marron:

I am enclosing three copies of the Final Progress Report for ONR contract # N00014-92-J-1581 titled "The Construction of a Compact, Inexpensive, Far Infrared FEL". Also enclosed is one copy of each of the papers written by my group over the length of the contract.

Please contact me if you have any questions or comments concerning this material.

Very truly yours,
R H Pantell
Richard H. Pantell

Professor

ONR copy

U.L.C. 04020

JUL 27 1995

FINAL PROGRESS REPORT

Grant#: N00014-92-J-1581

R&T Code:s400074fel03

PRINCIPAL INVESTIGATOR: Professor Richard H. Pantell

INSTITUTION: Stanford University

GRANT TITLE: The Construction of a Compact, Inexpensive, Far Infrared FEL

REPORTING PERIOD: 1 April 1992 - 31 March 1995 (Final Report)

AWARD PERIOD: 1 April 1992 - 31 March 1995

OBJECTIVE: To develop a free electron laser (FEL) for the far infrared that will be modest in cost and size, and therefore be suitable for placement in an individual laboratory or hospital. The oscillator would operate in the range from 80 to 500 μ m, with megawatts of peak power and a 10 μ s macropulse.

APPROACH: The accelerator is compact and simple, consisting of a 1.5 cavity RF gun using a thermionic emitter and an accelerator length of 8cm. In this manner, beam energies in excess of 4MeV can be obtained which, for a wiggler period of 1cm, correspond to wavelengths shorter than 80 microns.

The wiggler consists of a staggered array of iron pole pieces in the field of a solenoid. Advantages of this design are that a strong wiggler field can be obtained with a short wiggler period; subsecond tuning over a 20-30% range is possible by varying the solenoid current; larger tolerances are possible than in a permanent magnet wiggler design; and a longitudinal magnetic field is present which helps to confine the beam.

The optical cavity uses a 2mm planar waveguide to confine the radiation in one transverse dimension, and two copper mirrors provide focusing in the orthogonal dimension. An on-axis hole is placed in the upstream mirror to permit both electron beam entry into the optical cavity without the need of a bending magnet, and optical radiation extraction.

ACCOMPLISHMENTS: The Far IR FEL (FIRFEL) lased at a wavelength of 86 μ m. We observed four orders of magnitude increase in power over the coherent spontaneous emission. The net gain was measured to be 21% compared with a theoretical gain of 25%.

The spectrum was measured with a Fabry-Perot interferometer. We found the spectral width to be $\Delta\lambda/\lambda = 6.3\%$ with an electron beam energy spread of $\Delta\gamma/\gamma = 3\%$. This is consistent with the expected spectral width to be $2 \Delta\gamma/\gamma$ from

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the FEL synchronism condition. As the energy spread is reduced the spectral width should approach the transform limit of 2%.

We have demonstrated the usefulness of the 1.5 cell RF gun as the sole accelerator for FIRFEL. The gun provides 5 A of peak current in a 1% energy spread and a sufficiently low emittance ($\epsilon_n = 10 \pi \text{ mm-mrad}$) for operation in the far IR.

The staggered array wiggler was demonstrated for the first time. The wiggler yielded a 11.4 kG peak field with a 1 cm period, 1 mm gap and a 7 kG solenoid driving field. The field had only a 1.2% rms variation with no prior selection of pole pieces.

The optical cavity demonstrated for the first time the ability of an on-axis hole in the upstream mirror to be used simultaneously for electron injection into the wiggler and radiation extraction from the optical cavity.

We measured the current transmission through the wiggler and determined that nearly 100% of the current entering the wiggler travels through the 2 mm gap of the wiggler the entire length of the uniform magnetic field region. With the optical planar waveguide formed by the wiggler, the FEL has two synchronous wavelengths. For the parameters of our system these wavelengths are 2.7 mm and 80-300 μm . We have seen spontaneous emission from both of these synchronous wavelengths. The emitted optical power was seen to vary as the square of the current and to exhibit constructive and destructive interference as the downstream mirror is translated longitudinally. This is a demonstration of coherent spontaneous emission initiated by the harmonic content of the electron beam.

SIGNIFICANCE: We have designed a far infrared FEL device at a component cost under \$300k. The FIRFEL is only several m^2 in size and the operation is simple enough to require only one operator. This transforms the FEL from the scale of a national facility or user center to the possibility of placing the FEL in an individual's laboratory or a hospital. The FEL's usefulness has been greatly enhanced by bringing the FEL to the user instead of vice versa.

PUBLICATIONS AND ABSTRACTS (last 3 years):

1. Y.C. Huang, H.C. Wang, R.H. Pantell, J. Feinstein, and J. Harris, "Performance characterization of a far-infrared, staggered wiggler," *Nucl. Instr. and Meth.*, A341, pp.431-5, 1994.
2. Y.C. Huang, H.C. Wang, R.H. Pantell, J. Feinstein, and J.W. Lewellen, "A staggered-array wiggler for far infrared, free-electron laser operation," *IEEE J. Quant. Elect.*, vol. 30, no. 5, pp. 1289-94, 1994.

3. Y.C. Huang, H. Wang, R.H. Pantell, J. Harris, J.F. Schmerge and J.W. Lewellen, "Electron beam characterization for a subcompact, far-infrared free-electron laser," to be published in *IEEE J. Quant. Elect.*, September, 1995.

4. J.W. Lewellen, J.F. Schmerge, J. Feinstein, R.H. Pantell and Y.C. Huang, "Preliminary emission characteristic measurements for a \$300k FIR FEL," *Nucl. Instr. and Meth.*, A358, pp. 24-6, 1995.

5. Y.C. Huang, R.H. Pantell, J.F. Schmerge and J. Feinstein, "Maximization of FEL gain for a hole-coupled resonator," *Nucl. Instr. and Meth.*, A358, pp. 315-8, 1995.

6. J.F. Schmerge, J.W. Lewellen, Y.C. Huang, J. Feinstein and R.H. Pantell, "The free-electron laser as a laboratory instrument," *IEEE J. Quant. Elect.*, vol. 31, no. 6, pp. 1166-71, 1995.

7. J.W. Lewellen, J.F. Schmerge, R.H. Pantell and J. Feinstein, "A subcompact free-electron laser," to be published in Proc. of the SPIE - the Inter. Soc. for Opt. Eng., Electron-Beam Sources of High-Brightness Radiation, vol. 2522B, 1995.